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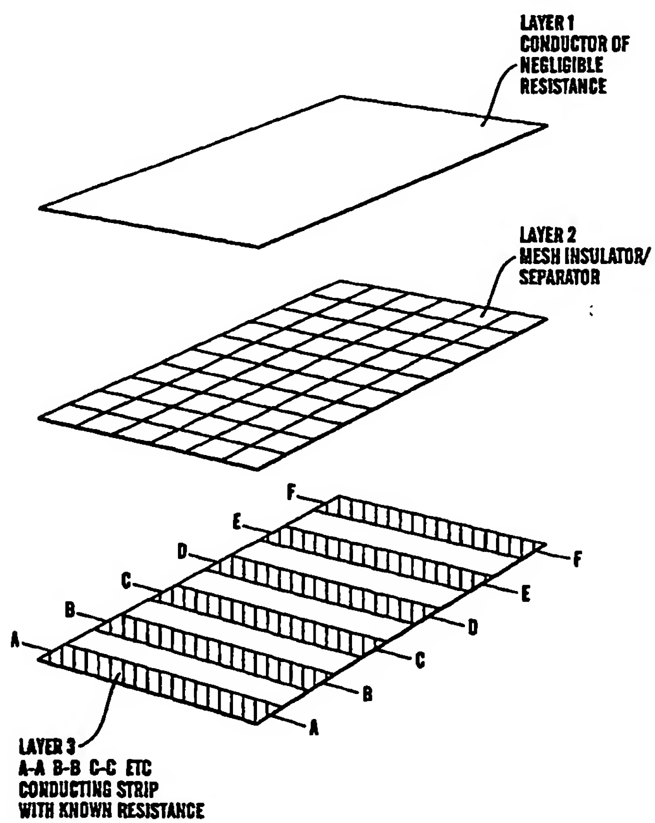
(54) Title: PRESSURE SENSOR

(57) Abstract

A pressure sensor includes upper and lower conductive layers (1, 3) separated by an intermediate insulating layer (2) which is formed as a separating mesh. The upper conductive layer (1) is of negligible resistance. The lower conductive layer (3) is formed of a plurality of conductive strips (A–F) separated by insulating strips. Each conductive strip (A–F) has a known resistance. An electrical signal is applied to the conductive strips (A–F) in turn and the electrical path between the upper and lower conductive layers (1, 3) then determined. The electrical resistance of the conductive path establishes the location of the pressure point at which bridging occurs and from this it is possible to establish the location and size of the pressure area.



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TACTILE PRESSURE SENSOR

The present invention relates to a pressure sensor, preferably formed from conductive fabric layers, for use, for example, in determining the type of pressure applied to an area.

There are applications, for example in hospital beds, where it would be advantageous to be able to obtain an accurate indication of pressure on a patient in order to be able to minimize the risk of or to treat bed sores and the like. No known system exists for performing this function.

According to an aspect of the present invention, there is provided a sensor capable of detecting applied pressure and providing information as to the area, location and/or extent of the pressure and including first and second conductive layers separated by an intermediate insulating layer, at least one of the first and second conductive layers including a plurality of conductive strips interdigitated with one or more insulating strips.

Preferably, the conductive strips have a known resistance.

The preferred embodiment provides an electrical switch and/or sensor, largely of fabric construction which is capable of detecting applied pressure and providing information as to the area and location of the pressure.

In the preferred embodiment, one of the layers is divided into a plurality of alternating conductive and insulating strips. The conductive strips have an electrical connection at either end. The electrically conductive strips can be used to determine the area and position of any contact between the two

outer layers through the intervening insulating layer due to pressure exerted upon the structure.

It has been found that the area subjected to a particular threshold pressure can be detected, together with its contour. This is particularly useful in applications in which the pressure points move or are moved.

In a preferred embodiment, fabric layers incorporating conductive fibers or yarns, normally held apart by separator means, can be brought into electrical contact by applying pressure across the layers, to act as an electrical switch.

A practical embodiment includes at least two sheets of woven or knitted textile formed from electrically conductive yarns, fibers or filaments. The layers can be separated electrically by at least one separator layer. The separator layer is of insulating material and can be in the form of raised bumps, a grid/mesh of any pattern, or stripes/bands. The thickness and spacing of the elements of the separator layer is such that when a certain level of pressure is applied across the thickness of the sheet assembly, electrical contact is made between the normally separate layers.

Advantageously, the separator means allows maximum flexibility and elasticity of the assembly in at least two axes without causing accidental bridging.

The invention also provides a method of measuring and interpreting electrical voltages and resistance across layers in contact, in order to obtain some information relating to the area of contact and to the position and shape of that contact.

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is an exploded view in perspective of an embodiment of a three-layer pressure sensor;

Figure 2 is a cross-sectional view in side elevation of the conductive and insulating strip structure of the preferred embodiment of lower conductive layer;

Figure 3 is a cross-sectional view in side elevation of the three-layer pressure sensor of Figure 1; and

Figures 4 and 5 are schematic diagrams of the pressure sensor showing an embodiment of a method of determining the area subjected to pressure, the pressure contour and/or determining the location of a single point of pressure without the need to use conductive strips on one of the conducting layers.

In the described embodiment, conductive fibers are incorporated into textile structures to form upper and lower conductive fabric layers. These layers are separated by an open mesh formed of a flexible insulating material. The three layers are assembled into a structure. The thickness of the separator layer, in combination with its scale of spacing and the flexibility of all the layers determine the pressure required to make contact between the conductive layers.

Referring to Figure 1, the embodiment of pressure sensor shown includes upper and lower conductive layers 1 and 3, separated by an intermediate insulating layer 2 which is formed as a separating mesh. The upper conductive layer 1 is of negligible resistance.

The lower conductive layer 3 is formed of a plurality of conductive strips A to F separated by insulating strips. Each conductive strip A-F has a known resistance.

Figure 2 shows an example of structure for the lower layer 3, being formed in this example in its warp fibers of five strands of insulator per insulating strip and four strands of conductive material for each conductive strip. In the example shown, the insulating strands are thicker than the conductive strands and can thus form the insulator layer between the two conductive layers 1 and 3, avoiding the need for a separate insulating layer.

More specifically, the effect produced is that the conductive warp yarns are below the surface level of the fabric when taken as a whole in a section running parallel to the weft. When two lengths of this fabric are arranged at right angles to each other, the conductive yarns will be separated from one another by an air gap. This air gap collapses when pressure is applied to the structure, thereby making electrical contact. The matrix of possible contact points or switches is determined by the size of the fabric sheet and the density of the conductive strips on each sheet. This in turn determines the definition of any area of contact.

The embodiment shown can act as a single stage pressure switch indicating when a certain level of pressure is applied to the assembly. In embodiments which may have more than two conductive layers, different levels of pressure can be sensed.

The position shape and area of any locations on the assembly which experience a pressure in excess of that needed to bridge an insulating layer could be determined as described below.

Layer 1, which is of negligible resistance, will short circuit any length of conductor on layer 3 with which it comes into contact. Given that the resistance of any conducting strip on layer 3 is known, then its change in resistance due to the length of contact with layer 1 will be directly proportional to that length of contact. By applying a voltage individually to the conductive strips and measuring any change in resistance the area of contact can be mapped and determined.

The measured resistance between one end of a conducting strip on layer 3 and its point of contact with the upper conducting layer 1 will be directly proportional to the free unconnected length of the conducting strip.

By repeating the process for the other end of the same strip then the length of contact and its position can be deduced.

Figure 3 shows this mechanism more clearly. When pressure is applied to the structure, the insulating layer 2 is bridged such that there is electrical contact between the two conductive layers 1 and 3. In practice, parts of the upper conductive layer 1 will touch one or more of the conductive strips of the lower conductive layer 3. An electrical path is thus created between the upper conductive layer, a part of one or more of the lower conductive strips and an electrical connection between the upper and lower layers 1 and 3. This can be seen in Figure 3, in which at the left-hand side of the Figure there can be seen an electrical circuit formed by a portion D1 of one of the lower conductive strips and part of the upper layer. As the resistance of each conductive strip A-F is known, the resistance R1 of the circuit thus formed is representative of the distance D1. Similar considerations apply to the right-hand side of the conductive strip A-F as shown in Figure 3, in which the resistance R2 of that circuit

is representative of the distance D2 of unbridged portion of the conductive strip A-F.

Thus, the area of pressure applied to this conductive strip A-F can be determined, the same being possible for all the other conductive strips A-F of the lower conductive layer 3 to produce a contour of the pressure applied to the structure. Approximations result from the depth of the separation layer and elasticity of the upper conductive layer and from the mark to space ratio of the conductive strips A-F. The specific structure of the lower conductive strip can be chosen for the particular application in dependence upon the resolution required.

Figures 4 and 5 show in better detail a mechanism for determining the pressure contour and/or its center.

Fig. 4 shows a plan view of the assembly with an indicated point, X, denoting the location at which the two outer layers have been brought into electrical contact.

If a potential difference is applied across E/G then the output from H will be a proportion of that voltage in to the ratio of the vector lengths of E/X:X/G. This ratio defines a line between E and G. A repeat of these steps using connectors F and I will define a second line and where the two intersect gives the location of X. Thus a single point of pressure or the center of an area or pressure can be located.
Referring now to Figure 5, having established the centroid of any area of contact by the previously outlined method, a vector can be defined from each connection point to the centroid. The resistance of the upper fabric layer will be negligible and the resistance of the lower fabric conductor layer will be known.

Therefore the measurement of resistance between any connection point on the lower layer to the upper layer will correspond to the distance along the vector from that point to the edge of the contact area.

For example the resistance between G and H will give the distance RG. The same process used for the other points will give the distances RI, RE and RF. These will give an approximation of the area.

It can be seen that an increase in the number of connection points will improve the definition of an area of contact by establishing extra vector distances to its periphery. Testing of a prototype sensor has given an indication of the shape of the region which is subjected to pressure above the threshold pressure to cause contact of the two conductive layers.

Assemblies similar to above example, where at least one additional conductive layer and separator means are added, are also possible. There would normally be used with separators of different thickness and/or spacing so that contact would be made between different layers at different degrees of pressure, to provide for example incremental pressure switch output.

Assemblies may also include at least two of the described layers largely created in a single pass during the weaving or knitting process.

It will be apparent also that two conductive layers 3 could be provided in an orthogonal configuration such that the conductive strips A-F of one layer cross at right angles those of the other layer. Point contact can thus easily be established.

The separator layers may be in the form of raised lumps of insulating fabric or other material, which may also be incorporated into the structure of one or both of the conductive sheets. Alternatively or additionally, they may be in the form of raised bars or stripes of insulating fabric or other material, which may also be incorporated into the structure of one or both of the conductive sheets.

It is also envisaged that the separator layers could be in the form or could include a "honeycomb" or other grid of insulating fabric or other material, which may also be incorporated into the structure of one or both of the conductive sheets; or of "drop-threads" of insulating fabric or other material, incorporated into the structure of one or both of the conductive sheets.

The assembly may have a waterproof coating or casing, or the fibers may be hydrophobic.

The fabric version of the sensor can be used where hard or sharp objects are undesirable, for example in toys, clothing or bedding; it is lightweight, low cost, comfortable, will conform to surfaces with compound curves (curves in up to three dimensions), versatile, may be incorporated into other fabric structures and can be made to be unobtrusive.

Thus it will be realized that the present invention relates to:

a) a pressure sensor; or
b) a pressure sensor that indicates the amount of pressure; or
c) a pressure sensor that indicates the amount of pressure and its area of application; or

d) a pressure sensor that indicates the amount of pressure, its area of application and the shape and location of that area,

achievable respectively employing:

a) a three layer assembly; or
b) a multi layer assembly, (the more layers, the greater the accuracy and range); or
c) a) or b) and arrange for resistance measurement to give the area; or
d) a) or b) with c) and further vectors or strips to determine the shape and location.

CLAIMS

1. A sensor for detecting applied pressure, including first and second conductive layers separated by an intermediate insulating layer, at least one of the first and second conductive layers including a plurality of conductive strips interdigitated with one or more insulating strips.

2. A sensor according to claim 1, wherein the conductive strips have a known resistance.

3. A sensor according to claim 1 or 2, wherein the sensor is substantially of fabric construction.

4. A sensor according to claim 1, 2 or 3, wherein one of the layers is divided into a plurality of alternating conductive and insulating strips.

5. A sensor according to any preceding claim, including one or more fabric layers incorporating conductive fibers or yarns, normally held apart by separator means forming the insulating layer.

6. A sensor according to claim 6, wherein the sensor includes at least two sheets of woven or knitted textile formed from electrically conductive yarns, fibers or filaments.

7. A sensor according to any preceding claim, wherein the insulator layer includes raised bumps, a grid/mesh of any pattern, or stripes/bands.

8. A method of detecting applied pressure by a sensor according to any preceding claim, including the steps of applying an electrical signal to one or more of the conductive

strips, measuring whether an electrical path is established between the conductive strip or strips and the other of the first and second layers and determining from each detected electrical path the pressure applied to the sensor.

9. A method according to claim 8, wherein the method includes determining the location of applied pressure on the basis of electrical resistance of each conductive strip.

10. A method according to claim 8 or 9, including the step of applying an electrical signal in sequence to a plurality or all of the conductive strips.

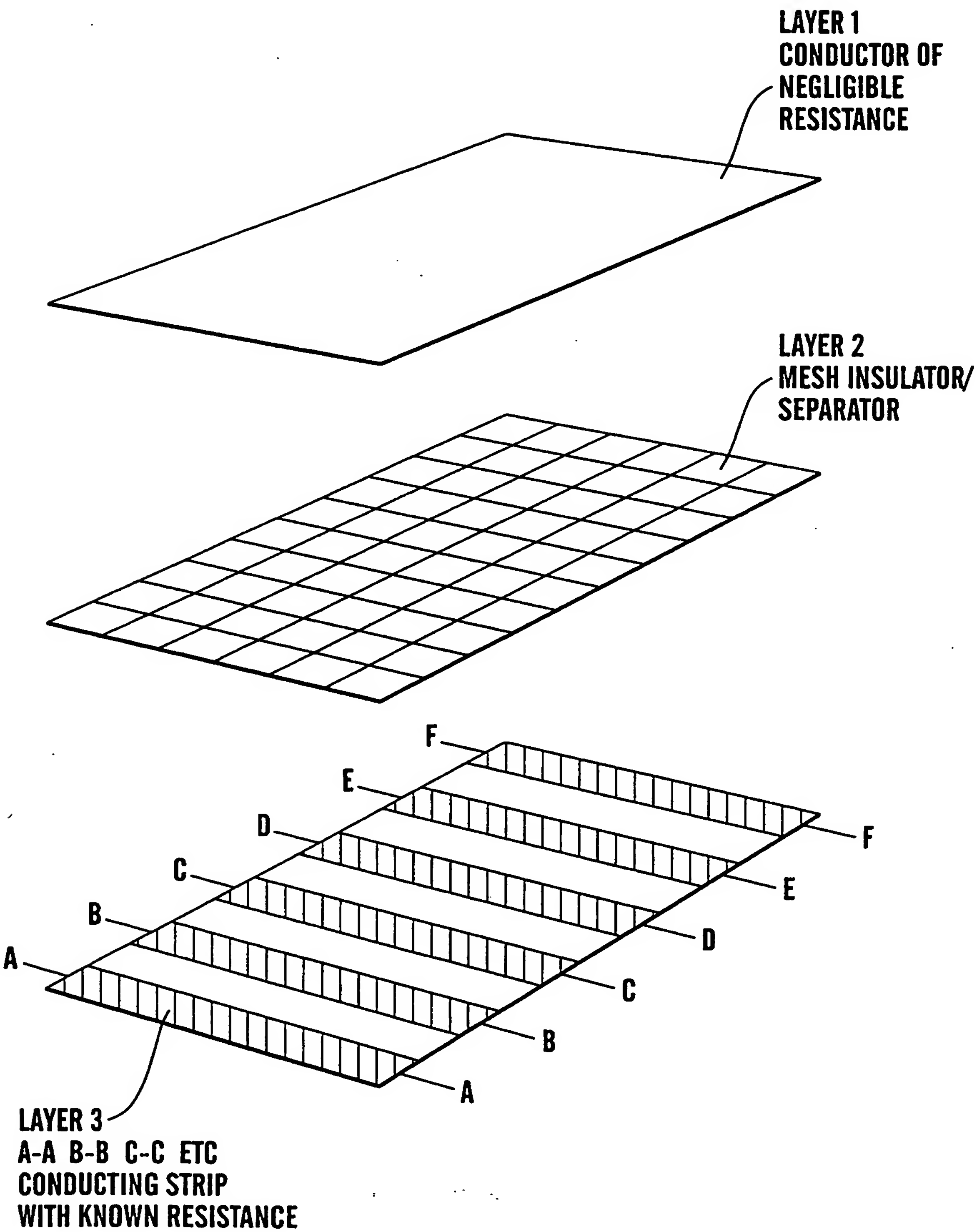

LAYER 1
CONDUCTOR OF
NEGLIGIBLE
RESISTANCE
LAYER 2
MESH INSULATOR/
SEPARATOR
F
E
D
C
B
A
F
E
D
C
B
A
LAYER 3
A-A B-B C-C ETC
CONDUCTING STRIP
WITH KNOWN RESISTANCE

Fig. 1

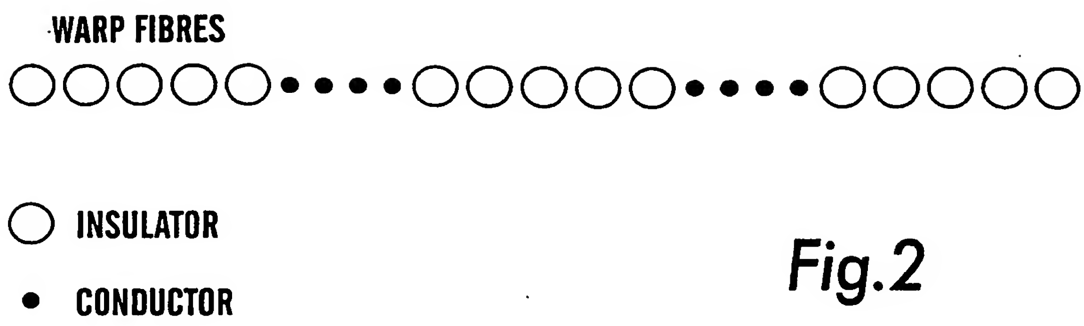
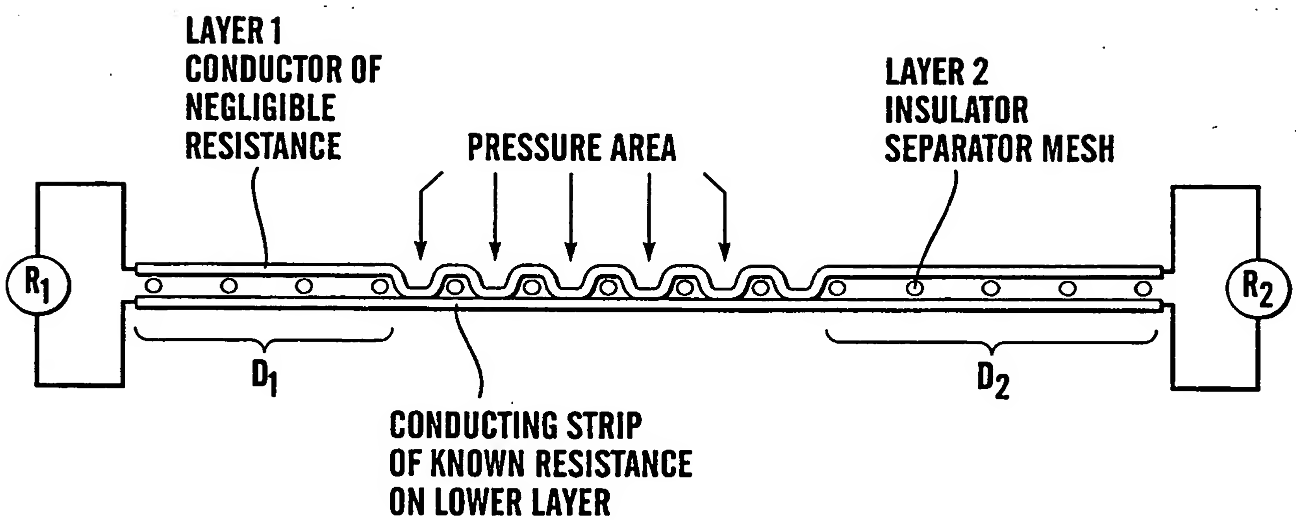


Fig.2



R = RESISTANCE D = DISTANCE

Fig.3

R_1 INVERSELY PROPORTIONAL TO D_1

R_2 INVERSELY PROPORTIONAL TO D_2

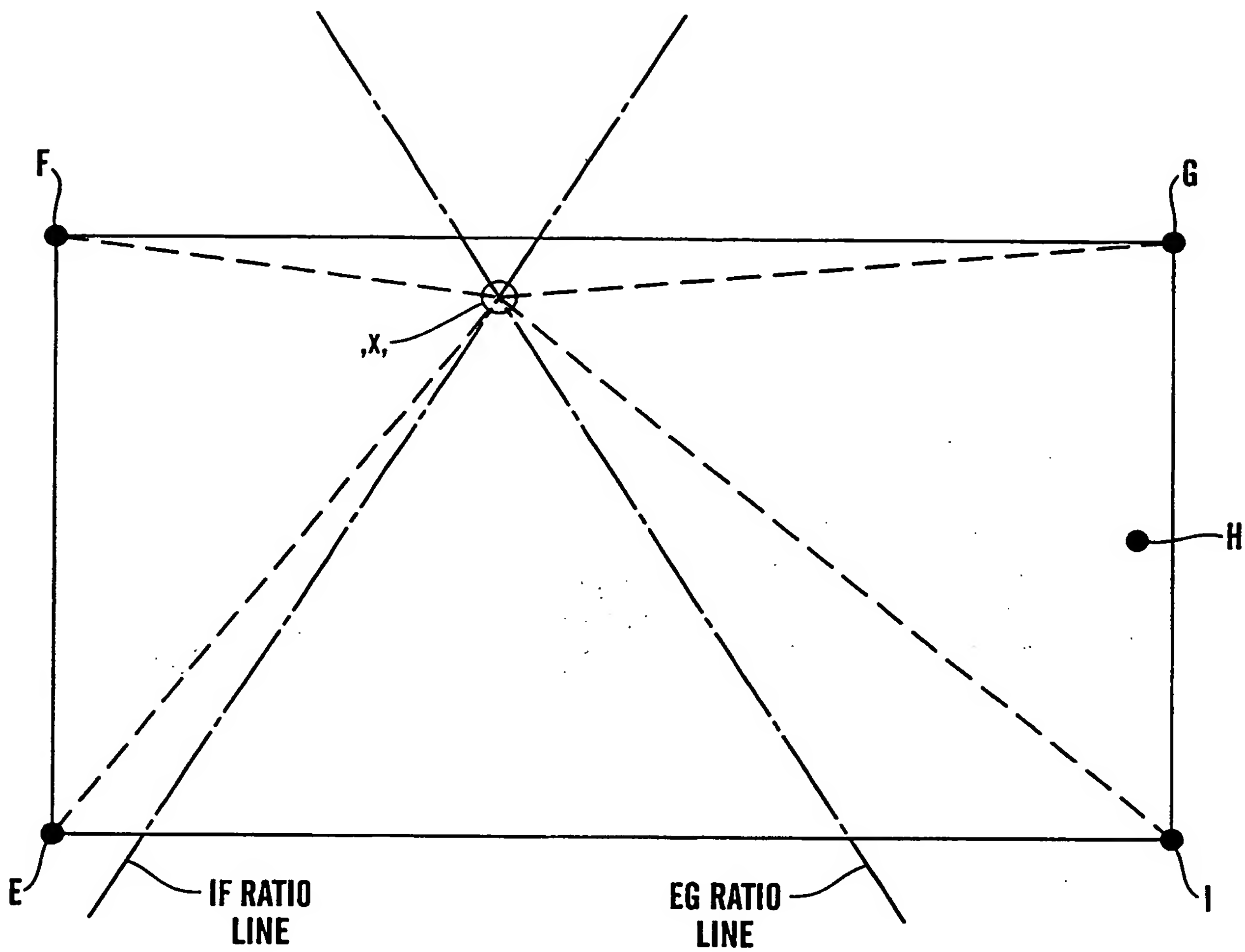


Fig.4

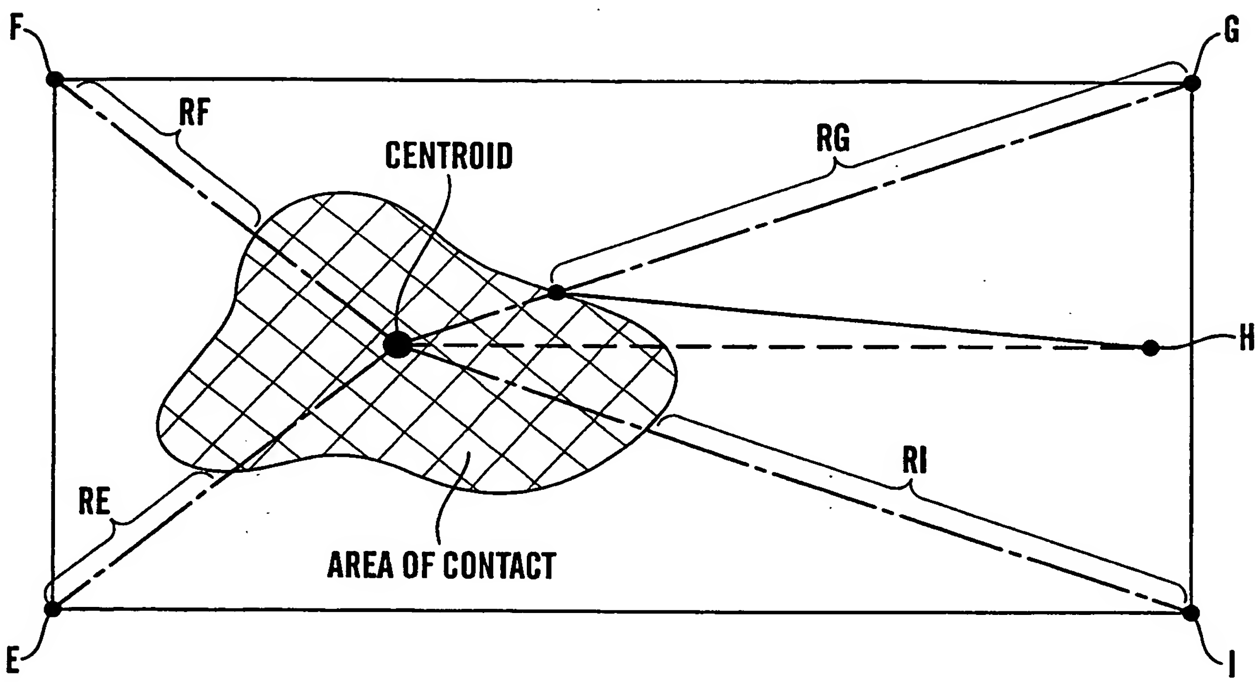


Fig.5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/03600

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01L1/20

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IPC 7 G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 014 224 A (R. HANS) 7 May 1991 (1991-05-07) column 2, line 51 -column 3, line 51; figures 1-4	1,2,4, 7-10
X	US 4 555 954 A (B.S. KIM) 3 December 1985 (1985-12-03)	1,2,4, 7-10
Y	the whole document	5,6
X	WO 86 05678 A (SENTEK, INCORPORATED) 9 October 1986 (1986-10-09) abstract; figure 1	1-3,7-10
X	DE 38 30 604 A (KOKOKU RUBBER TECHNOLOGIES INC.) 15 March 1990 (1990-03-15) column 3, line 33 -column 4, line 28; figures 1,2	1,2,7,8

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 99/03600

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